INTRODUCTION

The establishment of the Exclusive Economic Zone (EEZ) in 1983 by Presidential Proclamation opened for natural resource exploration a vast offshore frontier area contiguous to the United States and its territories. The EEZ extends from the seaward limit of state waters (3 nautical mi from shore) to 200 nautical mi offshore, and it includes the continental shelves. Within the context of the EEZ natural resource assessment effort, the purpose of this study is to delineate, on a regional basis, the potential for heavy-mineral placers on the U.S. Continental Shelf in the western and northern Gulf of Mexico from the United States-Mexico border to the Alabama-Florida state line. This map is intended to serve as a general guide for placer. exploration. It shows favorable sea-floor areas for placer occurrence in water depths ranging from 0 to 100 fathoms (600 ft). The map can be used as a guide for focusing costly exploratory efforts, such as coring operations and The potential economic value of heavy-mineral placer concentrations on the U.S. Continental Shelf is a function of both geologic and economic variables. Geologic variables include the composition and concentration of the heavymineral assemblages and their environment of deposition. Economic variables include the current world market price of extracted metals, as well as the cost of mining, processing, and marketing the metals. These economic factors, in turn, are tempered by the nation's socio-political climate, which determines its need for specific mineral resources at any given time.

This study divides the sea floor of the western and northern Gulf continental shelf into areas having low, moderate, and high potential for heavy-mineral placers. This division is based entirely on geologic criteria rather than on socio-economic or technological factors such as water depth or distance from processing and marketing

EVALUATION CRITERIA FOR PLACER POTENTIAL Surficial sea-floor sediment texture and composition

One of the most basic criteria for differentiating areas of placer potential is the texture of the surficial sea-floor sediments. Heavy-mineral placers are products of hydraulic fractionation in relatively high-energy environments. The residual deposits formed in such environments consist of relatively coarse grained sand and gravel; these are the light-mineral size fractions that would be in hydraulic equivalence (Rittenhouse, 1943) with the smaller and higher density heavy-mineral particles comprising potential placers. In contrast, clay- and siltsize sediments (mud) are the winnowed component of the hydraulic fractionation process, and they are generally deposited from suspension in lower energy environments. Although concentrations of ultra-fine heavy minerals can accumulate in such low-energy environments, present mining and beneficiation techniques generally are not capable of economically recovering heavy minerals in the less than 50 μ m particle-size range (Moore, 1978). The probability of placer resource occurrence increases as the sand+gravel:clay+silt ratio of the sea-floor sediment increases. Sea-floor areas composed of clean sand and gravel have the highest potential for heavy-mineral placers, whereas areas composed of mud have the lowest potential; areas composed of muddy sand or gravel have moderate In addition to texture, the gross mineralogy of the sea-floor sediment's light-mineral fraction is another indicator of placer potential. The major distinction is between siliciclastic and carbonate sea-floor deposits. The siliciclastic facies is the main source of heavy-mineral placers, whereas the potential for placer occurrence in a

A second criterion for evaluating heavy-mineral placer potential on the modern sea floor is the post-Tertiary history of the sea-floor sediment. As a result of glacioeustatic sea-level fluctuations, the continental shelves were alternately submerged and exposed; they were extensively modified by Quaternary erosional and depositional processes, which have an influence on where placers may be found. Sea-floor sediment areas that have a Quaternary history favorable for placer genesis could indicate favorable sites for placer occurrence. The origin of marine placers is not adequately understood to fully develop reliable offshore exploration models. However, there are basic requirements for placer formation that can be used in an exploratory program. Moore (1978) noted three requirements for the formation of marine placers: (1) appropriate heavy-mineral source rocks, (2) a transport conduit through which the sorting and mineral enhancement processes occur, and (3) an appropriate depositional site where heavy minerals can accumulate. An interpretation of the Quaternary history of sea-floor sediments, in relation to these three factors, can provide additional insight into placer potential. The most suitable source rocks for valuable heavymineral placers are igneous and metamorphic rocks. In contrast, terrigenous sedimentary rocks are relatively poor sources of valuable heavy minerals. The most important economic heavy minerals derived from sedimentary source

rocks are mature species such as zircon, rutile, and

Sediment history

carbonate facies is very low.

tourmaline; these species are commonly multicyclic minerals derived from reworked siliciclastic deposits. The formation of marine placers is dependent upon the presence of suitable onshore bedrock capable of providing economically significant quantities of heavy minerals. Some of the best areas for marine placers are adjacent to onshore coastal sites where economic placers have been mined (Emery and Noakes, 1968). However, the absence of onshore placers does not necessarily negate the possibility of offshore placer occurrence. As noted in studies of heavy minerals on the U.S. Atlantic Continental Shelf (Grosz and Escowitz, 1983; Grosz and others, 1985), relatively high concentrations of heavy minerals have been found in offshore areas adjacent to onshore deposits having low concentrations of heavy minerals. The absence of onshore placers should not be used to exclude adjacent offshore sectors from exploration A sediment history favorable for placer occurrence includes the development of a transport conduit and depositional site in which heavy minerals are hydraulically concentrated and deposited in economic quantities. Such concentration and deposition of heavy minerals generally occur within high-energy hydraulic regimes associated with fluvial or littoral environments. Therefore, geomorphic evidence on the continental shelf of relict deposits formed in these high-energy environments during lower stands of sea level may indicate favorable sites for placers. Evidence for near-surface relict fluvial-channel deposits can consist of surficial geomorphic expressions, such as present seafloor valleys. Evidence for relict littoral deposits also can consist of surficial geomorphic features. These features include linear sand shoals representing relict barrier-beach ridges, arcuate sand shoals representing former inlet-associated shoal complexes, and wave-cut terraces representing former strandlines. Relict placers developed in littoral environments are the best prospects for lower density heavy minerals (ilmenite, rutile, zircon, monazite); whereas fluvial placers are the best prospects for the higher density heavy minerals (gold, platinum, tin) and gemstones (Emery and Noakes, 1968). Although not used in the present study, evidence for relict fluvial and littoral deposits can also be obtained from seismic reflection profiles or from borehole data. In addition to relict placers, modern placers can develop under present hydraulic conditions in high-energy areas through selective sorting and heavy-mineral concentration by wave action or sea-floor currents. Such areas include modern beaches and adjacent shoreface

floor depressions are present that could serve as sinks or traps for heavy-mineral accumulations. Surficial heavy-mineral composition

sectors. Other areas might include deeper shelf localities

where winnowing sea-floor currents are strong and where sea-

A third criterion used for evaluating placer potential is the composition of surficial heavy minerals on the sea floor. In most reconnaissance studies, this type of information may be either absent or restricted to local areas. However, where available, this information should be used to further delineate favorable sites for placers. Quantitative data consisting of weight percentages of the total heavy-mineral fraction or of individual heavymineral species within the surficial sea-floor sediment can provide evidence of placer potential. Although such weight percentages are valid only for the water and sea-floor interface, they also can be used to infer subsurface conditions to delineate favorable areas for follow-up coring operations to ascertain the depth variability of heavymineral concentrations. Qualitative data regarding the composition of surficial heavy-mineral assemblages, in terms of mineral species present, also can provide evidence of placer potential. The presence or absence of valuable heavy minerals on the sea floor can be extrapolated to shallow depths, assuming a constant provenance, and can be used to eliminate areas having no economic potential. Furthermore, areas having heavy-mineral assemblages composed of more than one valuable mineral species could have substantially higher placer potential than areas containing a single valuable

MAP PREPARATION

On the basis of the three evaluation criteria, the map was constructed to illustrate the potential for heavymineral placers on the western and northern Gulf continental shelf. The continental shelf first was divided solely on the basis of surficial sea-floor sediment composition into areas of sediment having low, moderate, and high potential for placer occurrence. These three divisions were based on the relative proportions of siliciclastic mud (clay+silt) and sand as determined from sea-floor sediment composition and distribution data from the U.S. Department of Interior (1983). In the map area, there is only a small amount of terrigenous gravel-sized shelf sediment and it was not considered relevant in evaluating placer potential. There are also only small amounts of carbonate deposits in the map area, except for localized patch reefs. The continental shelf was divided as follows: high-potential areas-composed of clean siliciclastic sands (less than 25 percent terrigenous clay+silt); moderate-potential areas--composed of muddy siliciclastic sands (25-50 percent terrigenous clay+silt); and low-potential areas--composed of siliciclastic mud (greater than 50 percent terrigenous clay+silt). Division of the continental shelf sea floor into these three categories does not illustrate where placers are definitely present, but only where they might

occur. However, it does illustrate large low-potential areas of the continental shelf where placers most likely do not occur. Future exploratory efforts should be focused on the areas that have moderate to high potential. In further delineating favorable areas for placer occurrence, sea-floor bathymetry (Holland, 1970) was used to locate surface physiographic features suggestive of a sediment history favorable for placer genesis. Sea-floor physiographic features that suggest the presence of relict deposits formed in fluvial and littoral environments are shown on the map. Such surface features include valleys and depressions, wave-cut terraces, linear ridges, and arcuate shoals. In areas having moderate to high potential for heavy-mineral placers, the presence of these features increases the probability of placer occurrence. However, not all such sea-floor features were preserved during the lolocene transgression. Consequently, although these features can be used as positive evidence suggesting placer occurrence, their absence should not be used to eliminate prospective sites for further exploration. In addition to sea-floor sediment composition and physiography, areas were delineated on the map where published information on heavymineral compositions is available (see table 1), which

further contributes to an evaluation of placer potential. HEAVY-MINERAL PROVENANCE

The western and northern Gulf continental shelf is a terrigenous siliciclastic province. The geologic province adjacent to the continental shelf is the Gulf Coastal Plain, which is composed of sedimentary rocks of Mesozoic and Cenozoic age. The drainage basins of most coastal-plain rivers are localized within these sedimentary rocks, which could be the source of mature multicyclic heavy minerals such as zircon, rutile, and tourmaline. Adjacent to the Texas continental shelf, the only Texas Coastal Plain rivers that derive significant sediment from igneous and metamorphic crystalline rocks within their drainage basins are the Rio Grande and the Colorado River. The Rio Grande traverses Precambrian to Cenozoic igneous and metamorphic rocks from the Big Bend area of west Texas and northward. The Colorado River traverses some Precambrian crystalline rocks of the Llano uplift in central Texas. The Rio Grande and Colorado Rivers appear to be the two most important source rivers for the transport of heavy minerals onto the Texas continental shelf. The composition of heavy-mineral assemblages on the Texas continental shelf has been discussed by Goldstein (1942), Van Andel and Poole (1960), Van Andel (1960), Shideler and Flores (1976), and Flores and Shideler (1978). In general, regional variations in composition were controlled primarily by provenance. A distinctive southern ancestral Rio Grande delta mineral assemblage is characterized by a suite composed dominantly of opaque minerals, pyroxene, and garnet. In contrast, a northern ancestral Brazos-Colorado delta mineral assemblage is characterized by a dominantly tourmaline and greennornblende suite; a central interdelta area is characterized by a heavy-mineral assemblage resulting from the mixing of the suites from the two delta systems. East of the Brazos-Colorado delta, the Brazos-Colorado delta mineral assemblage mixes with a Mississippi River mineral assemblage characterized by a dominantly hornblende-pyroxene suite containing substantial epidote and garnet. The main heavy minerals of potential economic value on the Texas continental shelf are zircon, rutile, tourmaline, irnet, kyanite, and opaque minerals. The opaque minerals include magnetite, hematite, ilmenite, and leucoxene (mixtures of ilmenite and rutile alteration products). No significant onshore heavy-mineral mining activities presently occur along the adjacent Texas coastal zone that would indicate the presence of proximal offshore placers. However, there has been production of some metals (gold, silver, and lead) further inland along the Rio Grande Valley in west Texas and New Mexico (U.S. Geological Survey, 1970), which indicates the potential of this fluvial system as a transport conduit for valuable heavy minerals. In addition, a study by Shideler and Flores (1980) of the modern Rio Grande heavy-mineral assemblage in Texas illustrates that opaque heavy minerals (magnetite, hematite, ilmenite, and limonite) are the most abundant mineral group of the assemblage; the opaque-mineral content (frequency percent) ranges from 37 to 66 percent at localities along the length of the Rio Grande in Texas. This evidence suggests that the Rio Grande may have been a significant conduit for heavy minerals during Quaternary time. Three major coastal-plain fluvial systems drain into the Louisiana-Mississippi-Alabama continental shelf sector within the map area. At the western extremity of this sector, the drainage basin of the Sabine River is restricted to the coastal plain province; however, the two other major rivers supplying sediment to the Louisiana-Mississippi-Alabama continental shelf have more extensive drainage basins. The most prolific sediment source is the Mississippi River system, which drains the vast midcontinent region; this region is composed of a wide variety of source materials ranging from Quaternary glacial deposits to Precambrian igneous and metamorphic rocks. At the eastern extremity of the study area, the Tombigee-Alabama fluvial system, which terminates at the head of Mobile Bay, includes some Precambrian and Paleozoic sedimentary. igneous, and metamorphic source rocks of the southern Appalachian province within the drainage basin. The heavy-mineral assemblage on the Louisiana-Mississippi-Alabama continental shelf has been discussed by various workers (Goldstein, 1942; Van Andel and Poole, 1960:

Van Andel, 1960; Fairbank (1962). The Louisiana shelf west

of the Mississippi River bird-foot delta is characterized by

a Mississippi River assemblage (Mississippi province), consisting of a dominantly hornblende-pyroxene suite with substantial amounts of epidote and garnet. Near the western extremity of the Louisiana shelf, the Mississippi River mineral assemblage mixes westward with the Brazos-Colorado mineral assemblage of the northeastern Texas shelf, which is dominated by tourmaline and green hornblende. East of the Mississippi River bird-foot delta, the Mississippi River mineral assemblage mixes with an eastern Gulf assemblage characterized by a dominantly Appalachian-derived kyanite and staurolite suite, with substantial zircon and epidote. Heavy minerals of potential economic value on the Louisiana-Mississippi-Alabama continental shelf are opaque minerals (magnetite, hematite, ilmenite, leucoxene), zircon, rutile, tourmaline, garnet, kyanite, sillimanite, monazite, and xenotime. No significant onshore mining of heavymineral resources presently occurs along the adjacent coastal zone that would indicate the presence of proximal offshore placers. However, there has been substantial production of some metals (iron, lead, and zinc) further inland in the watershed area of the Mississippi River and its tributaries (U.S. Geological Survey, 1970); past production of metals also has occurred in the watershed areas of the Tombigbee-Alabama fluvial system (iron, gold, and copper) and the Sabine River (iron). These major fluvial systems could have been significant transport

conduits for valuable heavy minerals during Quaternary time.

PLACER POTENTIAL OF SEA-FLOOR SEDIMENT Solely on the basis of surficial sea-floor sediment characteristics, large areas of the continental shelf can be classified as having low potential for heavy-mineral placers (see map). These are areas where mud (clay and silt) is the dominant surficial sediment component. On the Texas continental shelf, these low-potential areas are found throughout most of the sector west of 95°20' W. longitude in water depths greater than 10 fathoms (1 fathom = 6 ft or 1.8m). An additional large low-potential area on the Texas shelf is in water depths shallower than 10 fathoms east of 95° W. longitude. On the Louisiana-Mississippi-Alabama continental shelf, low-potential muddy areas occur at all water depths and cover a large part of this shelf sector. These low-potential areas should be given lowest priority in placer exploratory programs. Areas that should be given high priority in placer exploration programs are the high-potential areas composed of clean sand and the moderate-potential areas composed of muddy sand. On the Texas continental shelf, these sandy areas mainly occur east of 95°20' W. longitude in water depths greater than 10 fathoms. Localized areas having moderate to high potential for placers are also found in mid-shelf water depths (25-50 fathoms) along two bathymetric salients that are in the southern and central part of the Texas shelf. These southern and central salients, respectively, represent relict topography of the ancestral Pleistocene and Holocene Rio Grande delta and the ancestral Brazos-Colorado delta complex. The sandy areas in the ancestral Rio Grande delta appear to be mostly relict deposits in disequilibrium with the present hydraulic regime; whereas, sandy areas in the ancestral Brazos-Colorado delta complex appear to be mostly reworked (palimpsest) deposits in partial equilibrium with present hydraulic conditions (Shideler, 1977). In addition to the deeper water relict and palimpsest sandy deposits, modern high-potential and moderate-potential sandy areas also occur in nearshore waters along the entire length of the Texas barrier shoreface sector The western half of the Louisiana continental shelf contains widespread sandy areas having moderate to high potential for heavy-mineral placers in water depths ranging from shallow coastal-zone waters to outer-shelf waters as much as 100 fathoms deep. These widespread western Louisiana shelf sands, in addition to the widespread eastern Texas shelf sands, appear to be mostly relict basal deposits of the Holocene transgressive series (Curray, 1960). Another large sandy area occurs at all water depths on the Mississippi-Alabama continental shelf east of the modern Mississippi River bird-foot delta. Especially significant is the widespread clean-sand area having high potential for placers, which covers most of the Alabama shelf. In addition to the foregoing main sandy areas, three small localized sandy areas occur on the eastern Louisiana shelf that have moderate or high potential for placers. SEA-FLOOR PHYSIOGRAPHY

The sea floor of the continental shelf has various relict physiographic features that suggest the presence of sediments deposited in former fluvial and littoral environments, which are preferential sites for the formation of placers. Where such physiographic features occur within high-potential and moderate-potential sandy sea-floor areas, the potential for local placer occurrences is substantially In the southern sector of the Texas continental shelf south of 27° N. latitude, relict physiographic features occur on the ancestral Rio Grande delta. These features include four terraces that probably represent former strandline positions along which substantial wave energy had been expended during a period of lower sea level. Two of these wave-cut terraces shoreward of the 25-fathom isobath are mostly over a low-potential muddy substrate and are not good sites for placers. However, the two terraces seaward of the 25-fathom isobath are partially coincident with a high-potential sandy substrate and are favorable placer sites. Another physiographic feature in this south Texas continental shelf sector that would be a favorable placer

ridge system in water less than 15 fathoms deep that is in an area having moderate to high potential for placers. The origin of the ridges is conjectural. They may be relict littoral depositional features, such as barrier-beach ridges or large-scale shoreface bedforms, or tectonic features, such as sea-floor fault scarps. Regardless of origin, the ridge system merits further exploration. The only other relict physiographic features in this sector are two short sea-floor valley segments in 10-20 fathoms of water, which occur over a low-potential area, and thus are not very favorable sites for placers. The central sector of the Texas continental shelf between 27° N. and 28° N. latitude has only one promising terrace in 25-50 fathoms of water; it occurs within an area having moderate to high potential, and it is a favorable placer site. The only other relict physiographic features on the central Texas shelf are two southwest-trending valleys in 50-100 fathoms of water, which are near the eastern margin of the shelf. These valleys occur within a lowpotential area. The northern sector of the Texas continental shelf north of 28° N. latitude has a large proportion of moderateto high-potential sandy areas, as well as several favorable relict physiographic features located within those areas. One of the most favorable placer sites is a ridge and valley system between 94° and 95° W. longitude that is parallel to the coast and is in less than 15 fathoms of water; the system is mainly within a high-potential area. Another favorable site located mainly in a high-potential area is an east-west-trending sea-floor valley with a flanking ridge between 95° and 96° W. longitude in 15-25 fathoms of water. Other possibly favorable placer sites in this sector occurring mainly in moderate- to high-potential areas are some isolated inner-shelf ridges and terraces, as well as mid-shelf and outer-shelf valleys with flanking ridges. On the western Louisiana continental shelf between 92°and 93°50' W. longitude, several relict physiographic features are present. Many of these features are coastparallel and coast-normal systems of valleys at all water depths, some having flanking ridges. Also present are inner-shelf terraces, as well as isolated inner-shelf and mid-shelf shoals. Some of these features occur in lowpotential areas that contain muddy sediment, and thus are unfavorable placer sites. However, several features do occur in moderate- to high-potential sandy areas, thus constituting favorable placer sites. One of the most favorable areas for placers on the western Louisiana shelf is a prominent inner-shelf shoal between 92° and 92°25' W. ongitude in a water depth of less than 5 fathoms. Most of this shoal is in a high-potential sandy area. Other favorable placer sites are a terrace and a series of coastparallel valleys and ridges west of 93° W. longitude in water depths of less than 50 fathoms. In the Louisiana continental shelf sector between 90° and 92° W. longitude, there are some relict features in sandy moderate- to high-potential areas that are favorable placer sites. These features occur mainly on the inner shelf in water depths generally less than 10 fathoms; they consist of a terrace-shoal complex between 91° and 92° W. ongitude, and a coast-parallel ridge between 90° and 91° W.

The continental shelf off easternmost Louisiana,

Mississippi, and Alabama (87°30'-90° W. longitude) contains

several relatively small-scale relict physiographic features

that could be favorable placer sites. These features are

essentially restricted to the eastern Mississippi-Alabama

continental shelf; they occur mainly in sandy moderate- to

trending valleys and a series of southeasterly trending

high-potential areas, generally in water depths of less than

25 fathoms. The dominant features include two southwesterly

site is a northerly trending, linear shoreface-connected

valleys and isolated depressions. These relict features appear to reflect paleoenvironments associated with a prograded fluvial-deltaic complex. SURFICIAL HEAVY-MINERAL CONTENT Available information on the total heavy-mineral content or the content of specific economically important minerals within surficial sea-floor sediment provides additional evidence for delineating favorable areas for placers on the continental shelf (see sources of heavymineral data in table 1). If favorable heavy-mineral contents are found within areas of high-potential or moderate-potential sediment, the probability of placer occurrence is substantially increased. Detailed mapping (Shideler and Flores, 1976) of the heavy-mineral distribution within the southwestern half of the Texas continental shelf (south of 28°20' N. latitude and west of 96° W. longitude) showed a relative abundance of total heavy minerals (in weight percent) on the southern ancestral Rio Grande delta. It also showed that south of about 26°45' N. latitude nearly all sea-floor sediment on the delta out to the shelf edge contains a total heavymineral content (63-250 μ m size range) in excess of 1 percent, and that several more local areas contain heavy minerals in excess of 4 percent; the maximum observed total neavy-mineral content was 32 percent. The abundant heavymineral assemblage of the ancestral Rio Grande delta generally contains an opaque-mineral fraction (magnetite hematite, ilmenite, and leucoxene) in excess of 40 frequency percent. The nonopaque fraction generally includes garnet,

Mapping by Shideler and Flores (1976) also illustrated that the total heavy-mineral content of continental shelf sediment decreases northward from the ancestral Rio Grande delta to the southwestern flank of the ancestral Brazos-Colorado delta complex (96° W. longitude), the eastern limit of their mapped area. Most of the sea-floor sediment between the northern margin of the ancestral Rio Grande delta (26°45' N. latitude) and the southwestern flank of the ancestral Brazos-Colorado delta complex contains less than 1 weight percent heavy minerals. This northward reduction of total heavy-mineral content is accompanied by a northward reduction in the proportion of opaque minerals. These regional gradients on the southwestern Texas shelf are paralleled by a similar northward reduction in the content of both heavy minerals and opaque minerals in adjacent beach and dune sediments along the length of the Texas coast (Shideler and Smith, 1984). The highest concentrations of total heavy minerals (weight percent) and opaque minerals (frequency percent) for both foreshore and adjacent dune sediments (63-125 μ m size range) are found within the southern coastal sector south of 27° N. latitude. The maximum concentrations in the foreshore sediments of this sector are 34 weight percent total heavy minerals and 73 frequency percent opaque minerals; dune sediments in this sector have maximum concentrations of 68 weight percent total heavy minerals and 74 frequency percent opaque In contrast to the southwestern half of the Texas continental shelf, very little quantitative data is available regarding total heavy-mineral concentrations or the concentrations of specific economically important minerals for the northeastern half (east of 96° W. longitude) of the Texas shelf. Van Andel and Poole (1960) and Van Andel (1960) noted that the Texas shelf east of 96° W. longitude contains a heavy-mineral assemblage resulting from the complex mixing of sediment from the Colorado, Brazos, Trinity, Neches-Sabine, and Mississippi Rivers. They provided data on the average frequency percentages of nonopaque minerals composing the assemblage, which includes garnet (7 percent), tourmaline (5 percent), zircon (4 percent), and kyanite (1 percent). However, they provided no information regarding total heavy-mineral or opaquemineral concentrations. One possible indication of total heavy-mineral concentrations (weight percent) on the Texas continental shelf east of 96° W. longitude is the concentrations within the beach sediments on the adjacent Texas coast (Shideler and Smith, 1984). Beach sediments in this sector contain a uniformly low (less than 3 weight percent) total heavymineral content that is similar to the content in beach sediments as far south as the northern limit of the ancestral Rio Grande delta (26°45' N. latitude). Consequently, it might be inferred that average heavymineral concentrations on the Texas shelf east of 96° W longitude are similar to those on the Texas shelf as far southward as the northern limit of the ancestral Rio Grande delta (generally less than 1 weight percent). This inference is supported by heavy-mineral data from a few sediment samples on the Texas shelf within the area east of 96° W. longitude (Goldstein, 1942). There is a scarcity of heavy-mineral concentration data for sediments on the Louisiana-Mississippi-Alabama continental shelf. Available information includes heavy mineral data presented by Goldstein (1942) from reconnaissance sampling of sediment on the northern Gulf shelf. On the basis of these samples, total heavy-mineral contents (weight percent) were found to be generally less than 1.5 percent, with a maximum content of 3.3 percent on the Mississippi shelf at a water depth of about 10 fathoms. His study also indicated a regional gradient of increasing ilmenite toward the east; the average content of ilmenite ranges from 6.2 percent (frequency percent of heavy-mineral fraction) on the Louisiana shelf to 27.0 percent on the Mississippi-Alabama shelf. Although Goldstein's (1942) study does provide some reconnaissance information, his sample localities were selected to establish-petrologic provinces in the northern Gulf, without having any particular relevance to evaluating placer Additional data on nonopaque heavy minerals of the Louisiana-Mississippi-Alabama continental shelf have been presented by Van Andel and Poole (1960) and Van Andel (1960). In terms of average frequency percentages of the nonopaque heavy-mineral fractions, they noted that the Mississippi River heavy-mineral assemblage, which is representative of most of the Louisiana shelf, contains the following potentially economic minerals: garnet (9 percent), tourmaline (2 percent), zircon (2 percent), and kyanite (<1 percent). They also noted that east of the Mississippi River bird-foot delta, an eastern Gulf assemblage contains kyanite (16 percent), tourmaline (12 percent), zircon (12 percent), and garnet (2 percent). The foregoing studies indicate that, with the exception of garnet, there is a regional eastward increase in the amount of potentially economic nonopaque heavy minerals on the Louisiana-Mississippi-Alabama continental shelf. Local studies offshore of the barrier-island system on the Mississippi-Alabama inner continental shelf also indicate an eastward increase in total heavy-mineral concentrations weight percent), with maximum concentrations being within the 2.4-3.6 percent range (Stow and others, 1976; Simonson and Meylan, 1983). A reconnaissance study of offshore

placer potential in the sea-floor area adjacent to this

and others, 1985). However, further seaward, the sandy

continental shelf areas shown on this map could have

significant placer potential.

parrier-island system produced discouraging results in terms

of locating economic heavy-mineral concentrations (Woolsey

This regional study indicates that the U.S. continental shelf in the western and northern Gulf of Mexico has potential for heavy-mineral placers in some areas. On the Texas continental shelf, the most favorable areas for heavy-mineral placers are on the ancestral Rio Grande delta south of 26°45' N. latitude in water depths of less than 50 fathoms. Parts of this delta sector have a favorable combination of surficial host-sediment composition and heavy-mineral concentrations, as well as relict physiographic features, that suggest a sediment history conducive to placer formation. A second favorable sector on the Texas shelf is the widespread sandy region north of 28° N. Matitude and east of 96° W. longitude in water depths less than 50 fathoms. This sector contains several relict physiographic features that occur within widespread moderate- to high-potential areas of sandy host sediment. However, sufficient supportive data on heavy-mineral concentrations within this sector are unavailable. A third sector having potential for heavy-mineral placers is the modern shoreface along the length of the Texas coast; the greatest potential in this sector is along the ancestral Rio Grande delta south of 26°45' N. latitude, where favorable host sediment is most widespread and heavy-mineral concentrations are highest. The central part of the Texas shelf between 27° N. and 28° N. latitude has only a single area having moderate to high potential for placers seaward of the shoreface; it is at 96° W. longitude in water 25-50 fathoms deep. Other areas of the central part of the Texas shelf do not appear to have potential for placers. On the Louisiana-Mississippi-Alabama continental shelf, one of the most promising areas for heavy-mineral placers is the western Louisiana inner continental shelf west of 91° W. longitude, in water depths of less than 15 fathoms. This area has a favorable combination of surficial sediment composition and relict physiographic features. The eastern half of the Louisiana shelf (89°-91° W. longitude) has mostly low potential for heavy-mineral placers; only one area at a depth of about 10 fathoms has high potential for placers. Much of the eastern Mississippi-Alabama shelf east of 89° W. longitude is another area that has moderate to high potential for heavy-mineral placers. This area has a

relatively high concentrations of economically significant

suggest favorable paleoenvironmental conditions for placer

heavy minerals, and relict physiographic features that

Geological Survey Circular 949, p. 16-17. favorable combination of widespread sandy host sediment,

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Table 1.--Published sources of heavy-mineral data for the western

| Study | Approximate number of shelf samples | Distribution of samples | Size fraction used | Type of data |
|--|---|-------------------------|-----------------------|--|
| Goldstein (1942) | 102 | Shelfwide | 0.062-2.00 mm | Total heavy minerals (weight percent), magnetite (weight percent), opaque minerals and translucent minerals (frequency percent) |
| Van Andel and Poole (1960) Van Andel (1960) | 320 | Shelfwide | 0.062-0.50 mm | Translucent minerals (frequency percent) |
| Fairbank (1962) | 63 | Area 1 (see map) | >0.074 mm | Total heavy minerals (frequency percent), opaque and translucent minerals (frequency percent) |
| Stow and others (1976) | 97 | Area 2 (see map) | >0.062 mm | Total heavy minerals (weight percent), opaque and translucent minerals (weight percent) |
| Drummond and Stow (1979) | 110 | Area 2 (see map) | >0.062 mm | Total heavy minerals (weight percent), opaque and translucent minerals (weight percent) |
| Shideler and Flores (1976) | 276 | Area 3 (see map) | 0.062-0.25 mm | Total heavy minerals (weight percent), total opaque minerals (frequencey percent) translucent minerals (frequency percent) |
| Flores and Shideler (1978) | 60 | Area 3 (see map) | 0.062-0.25 mm | Statistical analyses of: total opaque minerals (frequency percent), translucent minerals (frequency percent), heavy-mineral ratios |
| Simonson and Meylan (1983) | 51 | Area 4 (see map) | 0.062-0.210 mm | Total heavy minerals (weight percent), opaque and translucent minerals, (frequency percent) |
| Woolsey and others (1985) | 56 | Area 5 (see map) | 0.062-0.50 mm | Trend surface analyses of: total heavy minerals (weight percent), several opaque & translucent minerals, (frequency percent) |

HEAVY-MINERAL PLACER POTENTIAL MAP OF THE U.S. CONTINENTAL SHELF, WESTERN AND NORTHERN GULF OF MEXICO

zircon, rutile, and tourmaline. The relatively high heavy-

mineral content of the moderate- to high-potential sandy

favorable sites for placers.

areas of the ancestral Rio Grande delta makes them highly

Gerald L. Shideler

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